

# **Exhibit 12**

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# What is a Memory Rank?

The term rank was created by JEDEC, the memory industry's standards group, to distinguish between the number of memory banks on a module as opposed to the number of memory banks on a component, or memory chip. The concept of memory rank applies to all memory module form factors, though in general it tends to matter primarily on server platforms, due to the larger amounts of memory they manage.

A memory rank is a block or area of data that is created using some, or all, of the memory chips on a module. A rank is a data block that is 64 bits wide. On systems that support Error Correction Code (ECC) an additional 8 bits are added, which makes the data block 72 bits wide. Depending on how a memory module is engineered, it may have one, two, or four blocks of 64-bit wide data areas (or 72-bit wide in the case of ECC modules.) This is referred to as single-rank, dual-rank, and quad-rank. Crucial denotes this on the module label as 1Rx4, or 2Rx4, 2Rx8, or similar.

The x4 and x8 refer to the number of banks on the memory component or chip. It is this number, not the number of individual memory chips on a PCB, that determines the rank of the finished module. In other words, if a module has chips on both sides of the PCB, which makes it dual-sided, it can still be single-ranked, dual-ranked, or quad-ranked, depending on how those chips are engineered.

Because a rank is 64 or 72 bits, an ECC module made from x4 chips will need eighteen chips for one single rank ( $18 \times 4 = 72$ ). An ECC module made from x8 chips needs only nine of them for a rank ( $9 \times 8 = 72$ ). A module made from eighteen x8 chips would be dual-ranked ( $18 \times 8 = 144$ ,  $144/72 = 2$ ). An ECC module that has twice as many x8 chips becomes quad-ranked ( $36 \times 8 = 288$ ,  $288/72 = 4$ ).

Having a dual- or quad-ranked module is like having two or four DRAM modules combined onto one module. For example, you can instantly go from four single rank 4GB RDIMM modules to a single quad-rank 16GB RDIMM module (assuming the system is compatible with 16GB RDIMMs).

The drawback with higher ranked modules is that servers sometimes have a limit on how many ranks they can address. For example, a server with four memory slots may be limited to a total of eight ranks. This means you can install four single-ranked modules or

four dual-ranked modules but only two quad-ranked modules, as installing more would exceed the amount of ranks that can be addressed.

On matters of rank and rank limitations, we recommend that you consult the manufacturer’s documentation for guidelines and directions that apply to your specific system. Additional information on ranking and the systems it typically applies to can be [here](#) found .

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